GAMMA-RAY LARGE AREA SPACE TELESCOPE (GLAST) PROJECT

MISSION SYSTEM SPECIFICATION

Revision A

OCTOBER 10, 2002

GODDARD SPACE FLIGHT CENTER
GREENBELT, MARYLAND

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(GLAST)
PROJECT

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NASA Goddard Space Flight Center

Greenbelt, Maryland

GLAST PROJECT MISSION SYSTEM SPECIFICATION

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GLAST PROJECT MISSION SYSTEM SPECIFICATION

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CH-04	04/14/03	iv and 10.	CCR 433-0142.
CH-04a	05/01/03	Corrected page 34.	CH-03 and CH-04 were originally released together as part of CH-04. The approved change in CH-03 (per CCR 433-0126) to Figure 3-8 “Trapped Proton Environment” was inadvertently left out of the CH-04 release. This has been corrected in the CH-04a release. CH-04a supersedes all previous versions of this document.

CHANGE RECORD PAGE (continued)

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ISSUE	DATE	PAGES AFFECTED	DESCRIPTION
CH-05	05/21/03	v, 21, 23, 26 and 42.	CCR 433-0135 and 433-0139.
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CH-07	10/16/03	v and 9.	CCR 433-0189.
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CH-10	9/10/04	v, vii, viii 11, 14, 36, 37, 41	CCR 433-0258 and 433-0261

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Acronyms

b	bit
B	Byte
CCSDS	Consultative Committee for Space Data Systems
DN	Data Number
DL	Downlink
EU	Engineering Units
FITS	Flexible Image Transport System
Gb	Gigabit
GCN	Gamma Ray Burst Coordinates Network
GLAST	Gamma ray Large Area Space Telescope
GN	Ground Network
GOF	Guest Observer Facility
GPS	Global Positioning System
HEASARC	High Energy Astrophysics Science Archive Research Center
IOC	Instrument Operations Center
LET	Linear Energy Transfer
LETth	Threshold LET
MB	Megabyte
MBU	Multiple Bit Upset
MOC	Mission Operations Center
PB	Playback
RT	Real Time
SC	Spacecraft
SEB	Single Event Burnout
SEE	Single Event Effect
SEFI	Single Event Functional Interrupt
SEGR	Single Event Gate Rupture
SEL	Single Event Latchup
SET	Single Event Transient
SEU	Single Event Upset
SHE	Single Hard Error
SI	Science Instrument
SN	Space Network
SSC	Science Support Center
SSR	Solid State Recorder
TBD	To Be Determined
TBS	To Be Supplied
TBR	To Be Resolved
TDRSS	Tracking and Data Relay Satellite System
TID	Total Ionizing Dose
UL	Uplink
USN	Universal Space Network

1 Introduction

1.1 Purpose and Scope

This document responds to the Level 1 requirements for the Gamma-ray Large Area Space Telescope (GLAST) mission. It also responds to the system architectural requirements of the Announcement of Opportunity for GLAST, to the science requirements that are given in the Science Requirements Document, and to the operations concept that is described in the Operations Concept Document for the mission. Implementation of these requirements is accomplished in this document by defining the operational system that acquires the science data and by specifying the top-level requirements of the different elements of that system. These system requirements together with the requirements for the system elements and their interfaces constitute the level 2 requirements for the mission.

This document is structured according to the functional hierarchy for the system. This hierarchy extends down from the overall system to the major systems that are to be developed, namely, the observatory system and the ground system. Interface requirements are also developed for the launch vehicle and for the space-ground link.

1.2 System Architecture

The GLAST system is shown in hierarchical form in the architecture block diagram of Figure 1-1. The overall system is comprised of 3 segments. The flight segment includes the launch vehicle and the observatory, which consists of payload instruments and spacecraft. The ground segment is comprised of all of the operating centers and the communications networks that connect them. The space-ground segment consists of the systems that connect flight and ground segments. This architecture also provides the structure for the organization of this specification.

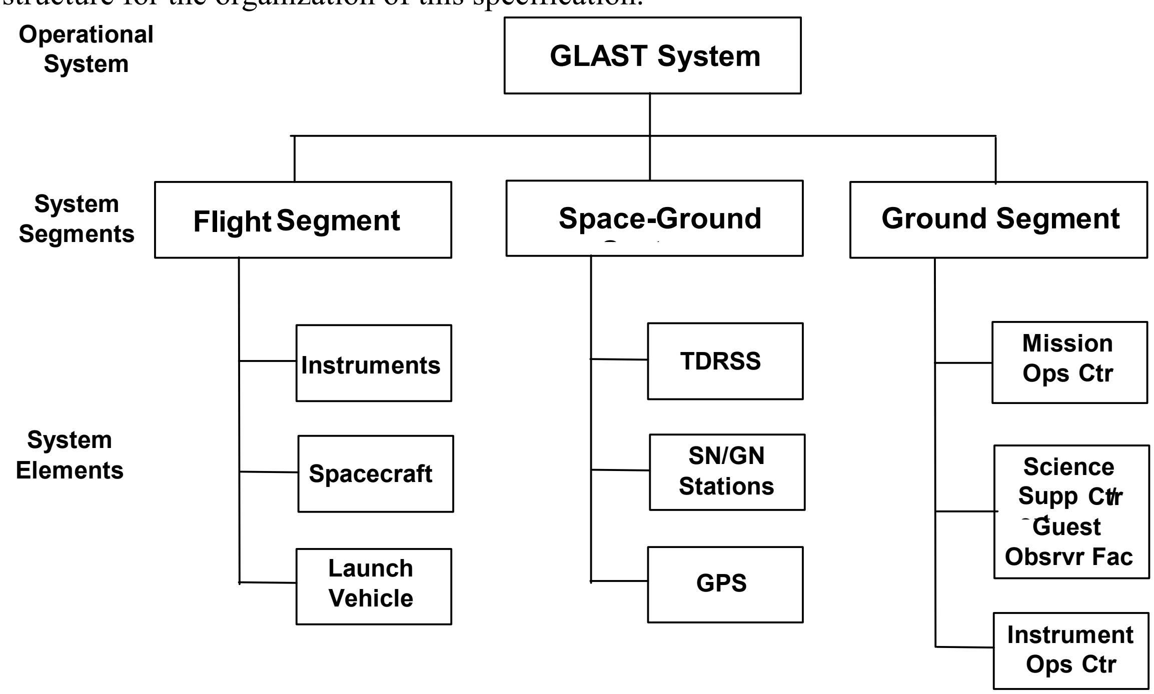


Figure 1-1 Architectural Block Diagram of the GLAST System

1.3 Flow Down Methodology

The purpose of flow down of a system requirement is to ensure that a requirement is recognized and addressed by a subsystem. Some requirements decompose; others do not. Requirements that do not compose flow down from system to subsystem by restatement, where the system requirement is restated in terms of the subsystem. System general requirements that are common to two or more subsystems are handled in this manner.

Requirements that do decompose are assigned at the system level to subsystems that implement the different aspects of the system requirement.

1.4 Definitions

The following definitions provide the meanings for the terms as they are used in this document.

Acceptance Stage: Period during which the deliverable flight item is shown to meet functional, performance, and design requirements under conditions specified for the mission.

Analysis (A): Predicted performance using calculations to show compliance with specified performance.

Autonomy: Performed without ground intervention.

Component: In the context of radiation environment requirements, the word "component" shall be interpreted to mean an active part, such as a microcircuit, electro-optical device, diode, etc.

Data Corruption: Probability of an undetected error in a block of data.

Demonstration (D): Observed compliance of functional operation or behavior with that specified.

Degradation: Reduction in the ability of an instrument to acquire data. This may be due to loss of performance, such as increased noise causing loss of sensitivity; or it may be due to partial loss of functionality that results from loss of some, but not all, channels of the same kind.

Development Stage: Prior to the manufacturing of flight hardware.

Disposal Stage: The period during which disposal requirements are verified.

Failure: Loss of functionality, i.e., the loss of the ability to perform a function, at any level (part, component, system).

Investigator: A GLAST investigator is any scientist who is authorized to use the GLAST system for the acquisition and analysis of data.

Inspection (I): Visual proof of existence of specified characteristics or properties.

Jitter: Unwanted high-frequency motion (outside the control bandwidth of the attitude control system) of the instrument line of sight. If the line of sight moves during an "exposure," or CCD integration time, the image is smeared. Jitter is most meaningfully specified in terms of peak-to-peak angular variation and time duration. The time interval of interest is the integration time of the detector, and the peak-to-peak angle requirement is bounded by the amount of image smearing that is acceptable for science.

LAT Central Field of View: Defined as within 30 degrees of the +Z axis.

Latency: Age of the oldest data in an acquisition period.

Linear Energy Transfer (LET): A measure of the energy deposited per unit length as an energetic particle travels through a material. The common LET unit is MeV*cm2/mg of material (Si for MOS devices, etc.).

Measurement: Comparison of data against a scale.

Mode: A specific configuration and set of operations or behavior that accomplish a given purpose.

Multiple Bit Upset (MBU): An event induced by a single energetic particle such as a cosmic ray or proton that causes multiple upsets or transients during its path through a device or system.

Observation: Acquisition of data without evaluation against a measurement scale.

Observing Efficiency: Fraction of time available that is spent acquiring data. On this mission the time available is the time on orbit less down time in the South Atlantic Anomaly.

Operational Verification Stage: Post launch period in which the flight system is verified to operate in space environment conditions and in which requirements demanding space environment are verified.

Pointed Observation: Observation in a commanded direction for a commanded duration.

Pointing Direction: The direction in which the observatory +Z axis points. This may be commanded to point to a target, or follow a survey profile, and may be adjusted in response to constraints or other considerations.

Pointing Accuracy: Difference between commanded (desired) direction and actual direction, comprised of control error, c, plus measurement error, k. See Figure 1-2. CH-01

Pointing Knowledge: Difference between actual direction and the (measurement) estimate. See Figure 1-2. CH-01

Qualification Stage: Period during which the flight or flight-type item is shown to meet functional, performance, and design requirements under conditions more severe than acceptance conditions.

Redundant: Availability of more than one path or method for accomplishing a given function.

Reliability: Probability that at least the essential components have survived at the end of design life. For spacecraft components, it is usually fairly clear what is essential. For example, if you have 2 of anything, like batteries, transponders, etc., and you lose both of them, the mission is over. For instrument components, where there are multiple redundancies, what is essential is determined by what data the customer is willing to pay for in continued operations.

Repoint Observation: An interruption of an on-going scan or pointed observation to temporarily observe a transient target.

Scan Observation: Continuous rotation of the pointing direction about the orbit normal.

Single Event Burnout (SEB): A condition, which can cause device destruction due to a high current state in a power transistor.

Single Event Effect (SEE): Any measurable effect to a circuit due to an ion strike. This includes (but is not limited to) SEUs, SHEs, SELs, SEBs, SEGRs, and Single Event Dielectric Rupture (SEDR).

Single Event Functional Interrupt (SEFI): A condition where the device stops normal functions and usually requires a power reset to resume normal operations. It is a special case of SEU changing an internal control signal.

Single Event Gate Rupture (SEGR): A single ion induced condition in power MOSFETs, which may result in the formation of a conducting path in the gate oxide.

Single Event Latchup (SEL): A condition, which causes loss of device functionality due CH-01
to a single event induced high current state. An SEL may or may not cause permanent device damage, but requires power strobing of the device to resume normal device operations.

Single Event Transients (SETs): These are “soft” errors in which a reset or rewriting of the device causes normal device behavior thereafter.

Single Event Upset (SEU): A change of state or transient induced by an energetic particle such as a cosmic ray or proton in a device. This may occur in digital, analog, and optical components or may have effects in surrounding interface circuitry (a subset known as Single Event Transients (SETs)).

Single Hard Error (SHE): An SEU, which causes a permanent change to the operation of a device. An example is a stuck bit in a memory device.

Target: A point in the celestial sphere, which is of scientific interest.

Test (T): Measurement of performance to show compliance with specified performance.

Threshold LET (LETth): The maximum LET at which no effects are noted or, alternately, the minimum LET to cause an effect at a particle fluence of 1E7 ions/cm2. Typically, a particle fluence of 1E5 ions/cm2 is used for SEB and SEGR testing.

Total Ionizing Dose (TID): The mean energy imparted by ionizing radiation to a sensitive device region divided by the mass of the region. This is typically given in units of rad(Si), where 1 rad(Si) = 100 erg deposited per gram of silicon.

Verification: The process of proving that the implementation satisfies the requirement. The central question is whether the system is built right. The methods of showing compliance with requirements are Inspection, Demonstration, Analysis and Test, as defined above.

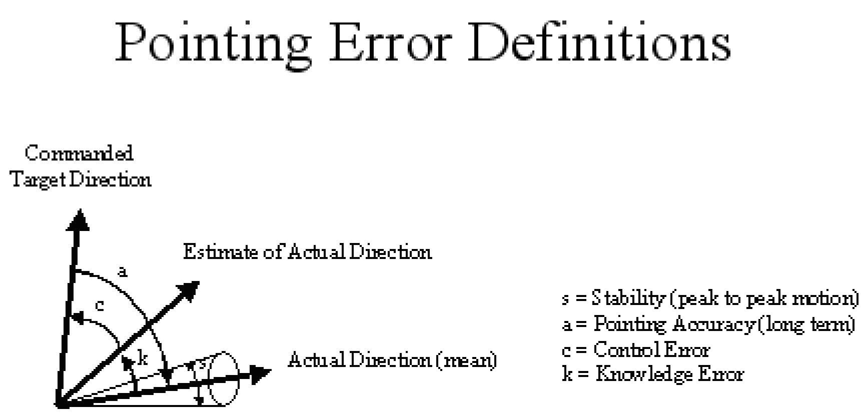


Figure 1-2 Pointing Error Definitions CH-01

2 Applicable and Reference Documents

2.1 Applicable Documents

The following documents contain requirements that are invoked by this Mission System Specification.

433-SRD-0001, GLAST Science Requirements Document

Delta II Payload Planners Guide, MDC 00H0016, October 2000. http://www.boeing.com/defense-space/space/delta/docs/DELTA_IIPPG_2000.PDF

CCSDS 101.0-B-5: "Recommendation for Space Data Systems Standards. Telemetry Channel Coding." Blue Book. Issue 5. June 2001

CCSDS 102.0-B-5: "Recommendation for Space Data Systems Standards Packet Telemetry." Blue Book. Issue 5. November 2000.

CCSDS 103.0-B-2: "Recommendation for Space Data Systems Standards Packet Telemetry Service Specification." Blue Book. Issue 2. June 2001.

CCSDS 201.0-B-3: "Recommendation for Space Data Systems Standards Telecommand Part 1 -- Channel Service." Blue Book. Issue 3. June 2000.

CCSDS 202.0-B-3: "Recommendation for Space Data Systems Standards Telecommand Part 2 -- Data Routing Service." Blue Book. Issue 3. June 2001.

CCSDS 202.1-B-2: "Recommendation for Space Data Systems Standards Telecommand Part 2.1 -- Command Operation Procedures." Blue Book. Issue 2. June 2001.

CCSDS 203.0-B-2: "Recommendation for Space Data Systems Standards Telecommand Part 3 -- Data Management Service." Blue Book. Issue 2. June 2001.

CCDS 701.0-B-3: "Recommendation for Space Data Systems Standards Advanced Orbiting Systems, Networks and Data Links: Architectural Specification." Blue Book. Issue 3. June 2001.

NSS 1740.14, NASA Safety Standard, Guidelines and Assessment Procedures for Limiting Orbital Debris, August 1995.

GEVS-SE Rev A. General Environmental Verification Specification for STS and ELV Payloads, Subsystems, and Components, June 1996. http://arioch.gsfc.nasa.gov/302/gevs-se/toc.htm

NPD 8010.2C, NASA Policy Directive, Use of the Metric System of Measurement in NASA Programs, July 2000.

NPD 2810.1, NASA Policy Directive, Security of Information Technology, October 1998.

NPD 2820.1, NASA Policy Directive, NASA Software Policies, May 1998.

NPD 8610.7, NASA Policy Directive, Launch Services Risk Mitigation Policy for NASA-Owned Or NASA-Sponsored Payloads, February 4, 1999.

Recommendation ITU-R SA.1157: Protection Criteria for Deep-Space Research (1995).

2.2 Reference Documents

The following documents are for reference only.

433-OPS-0001, GLAST Operations Concept Document.

Announcement of Opportunity, Gamma Ray Large Area Space Telescope (GLAST) Flight Investigations, NASA AO 99-OSS-03, March 1999.

3 Requirements

3.1 System Requirements

System requirements are the requirements that are common to all system elements.

3.1.1 General Requirements

General requirements are requirements that do not decompose. They flow down from system to subsystems by identical restatement.

3.1.1.1 Launch Date

The design, development, and operational readiness of the GLAST system shall meet the launch date specified on the master schedule for the project.

3.1.1.2 Lifetime

3.1.1.2.1 In-Orbit Checkout Period

The in-orbit checkout period shall be up to 60 days.

3.1.1.2.2 Operational Lifetime

The operational lifetime of the GLAST system shall be a minimum of 5 years, with a goal of 10 years, following an initial period of in–orbit checkout.

3.1.1.2.3 Orbital Lifetime

The orbital lifetime shall not exceed 25 years beyond the operational lifetime as required by NSS 1740.14.

3.1.1.3 End of Life Disposal CH-07

3.1.1.3.1 Disposal Method CH-07

At the end of mission life, the method of disposal shall be compliant with NSS 1740.14.

3.1.1.3.2 LAT ACD Design for Demise

Each ceramic fiber layer of the ACD micrometeoroid shield shall be made up using individual sheets no larger than the +/-X, +/-Y, and +Z sides. The individual sheets shall be attached together using material that has a melting point that is less than 270° C. CH-07

3.1.1.3.3 LAT Tracker Design for Demise

The dimensions of the LAT tracker Tungsten converter foils shall be such that the volume of each piece is no greater than 3000 mm^3.

3.1.1.4 Orbit

3.1.1.4.1 Altitude

The initial orbit altitude shall be 565 km. CH-06

3.1.1.4.2 Inclination

Orbit inclination shall be equal to or less than 28.5 degrees.

3.1.1.4.3 Eccentricity

Initial orbit eccentricity shall be less than 0.01, as provided by the launch vehicle for circular orbit.

3.1.1.4.4 Altitude Range

The GLAST system shall meet all requirements at any orbit altitude between 575km and 450km.

3.1.1.5 Communications

3.1.1.5.1 Space-Ground Communications

The GLAST system shall use two paths for space-ground communications, a direct ground path, and a relay satellite path.

3.1.1.5.1.1 Direct Ground Path

The direct ground path shall provide the services to communicate the data types at the rates and center frequencies given in Table 1:

DATA TYPE	COMM. MODE	RATE kbps / Mbps	S-BAND FORWARD, GHz	S-BAND RETURN, GHz
Command	GN	2k	2.1064	
Telemetry, Combined Real Time and Playback	GN	≤ 2.5 M		2.2875

CH-06

CH-03

Table 1. Rates and Frequencies for Direct to Ground Link

3.1.1.5.1.2 Relay Satellite (TDRSS) Path

The relay satellite path shall provide the services to communicate the data types at the rates and center frequencies given in Table 2:

DATA TYPE	COMM. MODE / SERVICE	RATE kbps / Mbps	Ku-Band Return, GHz	S-BAND FORWARD, GHz	S-BAND RETURN, GHz
Stored Science, Stored and Real-Time Housekeeping, Alerts, Stored and Real Time Diagnostic Data	SN / KSA	40 Mbps	15.003		
Command / Software Loads	SN / SSA	4 k		2.1064	
Telemetry, Real Time	SN / SSA	Ground Selectable 1 k, 2 k, 4 k, 8 k			2.2875
Target of Opportunity	SN / SMA	0.25 k		2.1064	
Alerts	SN / SMA	1 k			2.2875

CH-06

CH-03

CH-04

Table 2. Rates and Frequencies for TDRSS Link

3.1.1.5.1.3 Instrument Data Throughput

The GLAST system shall be designed to accommodate instrument data rates and volumes as defined in the LAT and GBM IRDs.

3.1.1.5.1.4 Telemetry Contacts

The GLAST system shall be capable of downlinking up to 30 hours of recorded science and 36 hours of housekeeping telemetry data. For the purposes of this requirement, the data is assumed to be continuously collected at orbit averaged rates. CH-08

3.1.1.5.2 Spectrum Management

3.1.1.5.2.1 Spectrum and Bandwidth

The GLAST system shall comply with national and international requirements, recommendations and agreements regulating the use of RF spectrum and bandwidth.

3.1.1.5.2.2 Deep Space Network

The GLAST system shall comply with Recommendation ITU-R SA.1157: Protection Criteria for Deep-Space Research (1995).

3.1.1.5.3 Ground Station Compatibility

The GLAST system shall be compatible with existing commercial ground stations, such as Universal Space Network (USN) in Hawaii and Dongara, Australia. CH-01 CH-10

3.1.1.6 Coordinate Systems

3.1.1.6.1 Inertial Coordinate System

GLAST shall use the J2000 inertial coordinate system.

3.1.1.6.2 Right Ascension and Declination

Right Ascension (RA) and Declination (DEC) shall be used as a standard means of receiving and communicating pointing directions.

3.1.1.7 Units of Measurement

GLAST shall observe the current NASA policy directive, NPD 8010.2C, Use of the Metric System of Measurement in NASA programs.

Metric units shall be used with the following exceptions: Angular measure may be expressed in degrees, minutes, and seconds; Photon and particle energy may be expressed in eV; and English units may be used for mechanical fabrication.

3.1.2 System Operability Requirements

3.1.2.1 Observation Plans

The GLAST system shall carry out the observation plans of GLAST investigators.

3.1.2.2 Observation Modes

The GLAST system shall acquire science data in 3 basic observation modes, sky survey mode, pointed observation mode, and repointed observation mode.

3.1.2.3 Targets of Opportunity

The GLAST system shall accommodate requests submitted by the scientific community to observe targets of opportunity.

3.1.2.4 Transient Event Response

The GLAST system shall respond to gamma-ray bursts and other transient events that are detected on board.

3.1.2.4.1 Alert Transmission

The GLAST system shall automatically transmit an alert message of a transient event to the appropriate ground networks.

3.1.2.4.2 Repointing

The GLAST system shall be capable of repointing the observatory to observe qualified gamma-ray bursts.

3.1.2.5 Data Handling

3.1.2.5.1 Packets

3.1.2.5.1.1 Packetized Data

All instrument data shall be compliant with CCSDS Packet Telemetry Recommendations as defined in Series 100 Blue Books.

3.1.2.5.1.2 Ancillary Data

LAT and GBM shall transmit data packets containing all data necessary for stand alone processing on the ground. (Calibration and alignment data will be constructed separately from science data sets.)

3.1.2.5.2 VCDU Service

The GLAST system shall implement the multiplexed virtual channel data unit (VCDU) service of the CCSDS.

3.1.2.6 Validated Science Data

The GLAST system shall provide validated science data to the GLAST user community.

3.1.3 System Maintainability Requirements

3.1.3.1 Fault Handling Capability

The GLAST system shall provide the capability for resolving flight hardware and software faults and anomalies.

3.1.3.2 Special Operations

The GLAST system shall accommodate the following operations during the course of the mission.

3.1.3.2.1 Software Uploads
The GLAST system shall accommodate software uploads for the instruments and the spacecraft.

3.1.3.2.2 Calibration
The GLAST system shall perform calibration observations as required during the course of the mission.

3.1.3.2.3 System Checkout and Test On Orbit
The GLAST system shall support system checkout and tests in different on/off and operational configurations of observatory system components.

3.1.4 System Allocations

3.1.4.1 Alert Response Time
The alert response time shall be less than 7 seconds with a goal of less than 4 seconds from the time of spacecraft receipt of GRB notification from GBM or LAT to delivery to the Gamma-ray Coordinates Network (GCN) computer for 80% of all GRBs detected by the GBM or LAT.
The alert response time shall be met with the following allocations:

3.1.4.1.1 Alert Acquisition and Initiation of Transmission
The spacecraft shall initiate transmission of an alert message within 1 second of detection of a GRB by either science instrument.

3.1.4.1.2 Alert Transmission
The space-ground link shall transmit alert messages to its ground station in less than 5 seconds.

3.1.4.1.3 Ground Interface to GCN
The ground system shall transfer the alert message from the ground station to the GCN within 1 second.

3.1.4.2 Observing Efficiency
The GLAST system shall achieve an observing efficiency of at least 90 % with a goal of 95 %.

3.1.4.2.1 Degradations

3.1.4.2.1.1 Pointing Knowledge
Pointing knowledge shall remain within the knowledge allocation during all slews of the observatory in its normal observing modes.

3.1.4.2.1.2 Telemetry Transmission
Telemetry transmissions shall not degrade the on-going acquisition of science data.

3.1.4.2.1.3 Observing Plans

At least 2 observing plans (the current plan plus a backup) shall be available to the MOC for implementation at all times during the pointed observation phase of the mission.

3.1.4.2.2 Viewing Interruptions

3.1.4.2.2.1 Spacecraft Outages CH-03

The total time spent in outages that prevent acquisition of science data, i.e., those that result in safe mode, shall not exceed 1 % of the operational life of the mission. CH-10

3.1.4.2.2.2 Default Procedures

Observing plans shall include default procedures that avoid having the earth enter the central field of view of the LAT.

3.1.4.2.3 Data Loss

The total data loss of less than 2 % with a goal of less than 1 % in the data delivery part of the GLAST system shall be met with the following allocations:

3.1.4.2.3.1 Spacecraft Data Loss

The data loss allocated to spacecraft malfunctions that occur in the science data flow and that prevent delivery of acquired data (without incurring safe mode) shall not exceed 0.1 % of mission science data. CH-03

3.1.4.2.3.2 Ground System Data Loss CH-03

The total data loss in the data delivery part of the GLAST system, excluding Spacecraft Data Loss, shall be less than 1.9% with a goal of less than 0.9%.

3.1.4.3 Data Transport

3.1.4.3.1 RF Links

3.1.4.3.1.1 RF Communication Links

The GLAST end-to-end system shall use RF communications links that provide an uncoded bit error rate of 1×10^{-5} or less.

3.1.4.3.1.2 Space to Ground Data Transport

Space-ground communications for GLAST shall implement CCSDS Grade of Service 2 on all GN and TDRS-SA return links as defined in CCSDS 701.0-B-3. CH-06

3.1.4.3.2 Ground System Data Transport

The GLAST end-to-end system shall use land line communication links that provide error-free data transmission and delivery. “Error-free” performance may be achieved through a combination of error detection and correction methods and re-transmit capability.

3.1.4.4 Data Latency

The maximum data latency shall not exceed 120 hours.
The system data latency shall be less than 72 hours 95% of the time. This is allocated as follows:

3.1.4.4.1 On Board Storage Latency

The on board storage data latency for science data shall not exceed 36 hours.

3.1.4.4.2 Downlink and Transmission Latency

The data latency for downlink and transmission of science data to IOC and MOC shall not exceed 12 hours.

3.1.4.4.3 Start of Production Processing

The production of standard data products by the LIOC shall begin within 24 hours of receipt of data.

3.2 Launch Vehicle Requirements

3.2.1 General Requirements

3.2.1.1 Launch Vehicle Provider

GLAST shall use a launch vehicle and launch services compliant with the requirements for NASA-related missions as specified in NPD 8610.7. This NASA policy document requires the project to use a U.S. commercial launch vehicle and launch services. Under section 1.b of the policy, a non-U.S. vehicle may be used if a waiver is granted and/or launch is being provided at no cost to the government as part of an international cooperative mission.

3.2.1.2 Launch Date

The launch vehicle shall support a launch readiness date as specified on the master schedule.

3.2.1.3 Baseline Launch Vehicle

For design purposes prior to official selection, the baseline launch vehicle for the GLAST mission shall be the Delta II 2920H-10 with 3 meter fairing and 6915 payload attach fitting with secondary latch system.

3.2.1.4 Availability

The launch vehicle shall be available for purchase by NASA for the specified launch date.

3.2.1.5 Reliability

Launch Vehicle reliability shall be 95% or greater at 50% confidence level.

3.2.1.6 Orbit

3.2.1.6.1 Altitude

The launch vehicle shall provide an initial orbit altitude of 565 km. CH-06

3.2.1.6.2 Inclination

The launch vehicle shall provide an orbit inclination that is equal to or less than 28.5 degrees.

3.2.1.6.3 Eccentricity

The launch vehicle shall circularize the initial orbit to an eccentricity that is less than 0.01.

3.2.1.6.4 Tolerances

The tolerances on the above orbit parameters shall be as provided by the nominal performance of the launch vehicle.

3.2.2 Performance Requirements

3.2.2.1 Fairing envelope

The launch vehicle shall provide minimum useable fairing dimensions of 2.743 m diameter by 3.15 m height.

3.2.2.2 Throw Capability

The launch vehicle shall place the GLAST observatory in the specified orbit.

3.3 Observatory Requirements

Observatory requirements are the requirements that apply in common to the science instruments and to the spacecraft.

3.3.1 Observatory General Requirements

3.3.1.1 Observatory Launch Date

The observatory shall be designed for an observatory launch date as specified on the master schedule for the project.

3.3.1.2 Design Life

The design life of the observatory shall be a minimum of 5 years, with a goal of 10 years, following an initial period of in–orbit checkout.

3.3.1.3 In-Orbit Checkout

3.3.1.3.1 Overall Period

The overall period for in-orbit checkout of the observatory shall not exceed 60 days.

3.3.1.3.2 Initial Phase

An initial period of up to 10 days of in-orbit checkout is allocated to the spacecraft with the remainder allocated to the science instruments.

3.3.1.4 Orbit

3.3.1.4.1 Altitude

The initial orbit altitude shall be 565 km. CH-06

3.3.1.4.2 Inclination

Orbit inclination shall be equal to or less than 28.5 degrees.

3.3.1.4.3 Eccentricity

Initial orbit eccentricity shall be less than 0.01, as provided by the launch vehicle.

3.3.1.4.4 Altitude Range

The observatory shall meet all requirements at any orbit altitude between 575 km and 450 km.

3.3.1.5 Observatory Reliability

3.3.1.5.1 Credible Failures

Except for structural assemblies, including pressure vessels, no credible single point failure shall jeopardize the mission.
No two credible failures shall cause loss of life or damage to surrounding facilities (transporters, launch pads, launch vehicle, etc.).

3.3.1.5.2 Observatory Reliability

The GLAST observatory shall achieve an overall mission reliability of > 70 % at 5 years.

3.3.1.5.2.1 Spacecraft Reliability Allocation

Spacecraft reliability shall be at least 85 % with a goal of 90 % at 5 years.

3.3.1.5.2.2 LAT Reliability Allocation

LAT reliability shall be at least 85 % with a goal of 90 % at 5 years.

3.3.1.6 Coordinate Systems

3.3.1.6.1 Inertial

3.3.1.6.1.1 J2000 System

The observatory shall use the J2000 inertial coordinate system.

3.3.1.6.1.2 Right Ascension and Declination

RA and DEC shall be used as a standard means of receiving and communicating pointing directions.

3.3.1.6.2 Body Fixed

The observatory shall use a right-handed coordinate system fixed in the observatory body, as shown in Figure 3-1. The origin of the body-fixed coordinate system shall lie in the separation plane of the launch vehicle Payload Attachment Fitting (PAF). The Z-axis shall be collinear with the geometrical centerline of the observatory. The +Z direction shall lie along the center of the LAT field of view. The Y-axis shall be parallel to the solar array drive axes. The -X axis shall be the anti-sun side. The +Y-axis shall be the cross-product of the +Z-axis and the +X-axis. The terms Roll axis, Pitch axis, and Yaw axis shall refer to the X, Y, and Z observatory axes, respectively. CH-01

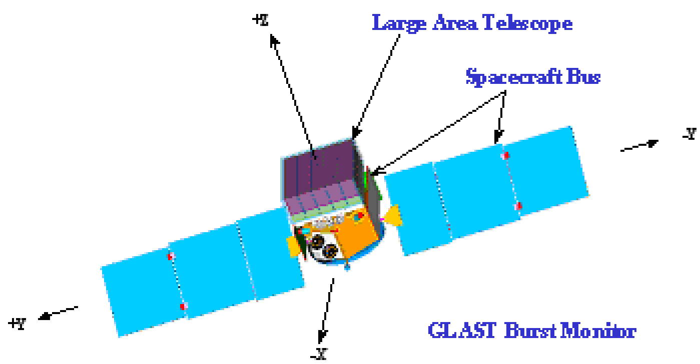


Figure 3-1 Observatory Coordinate System CH-01

3.3.1.6.3 Orbit Fixed

An orbit-fixed frame ("orbit frame") is defined as follows:
The origin is coincident with the origin of the Body-Fixed frame defined above.
The $+Z_o$ axis points to the instantaneous Zenith direction.
The $+Y_o$ axis points along the positive orbit normal.
The $+X_o$ axis is the cross product of $+Y_o$ and $+Z_o$. For a circular orbit, $+X_o$ points along the positive velocity direction.
The orbit-fixed frame rotates with respect to the inertial frame at orbit rate about the $+Y_o$ axis.
The orbit plane coincides with the $+X_o$-$Z_o$plane.
A vector direction is defined with respect to the orbit frame by specifying two angles: an in-plane angle and a rocking angle. The rocking angle is the angle between the vector and the orbit plane, and is positive when the vector's Y_o component is negative. The inplane angle is the angle between the vector's projection onto the orbit plane and the $+Z_o$ axis, and is positive when the vector's X_o component is positive.

3.3.1.6.4 Pointing Axis
The axis for pointing direction of the observatory is defined as the +Z axis.

3.3.1.7 Units of Measurement
The observatory shall observe the current NASA policy directive, NPD 8010.2C, Use of the Metric System of Measurement in NASA programs.

The observatory shall use metric units with the following exceptions: Angular measure may be expressed in degrees, minutes, and seconds; Photon and particle energy may be expressed in eV; and English units may be used for mechanical fabrication.

3.3.1.8 Data Standards
The observatory shall employ the recommendations of the Consultative Committee on Space Data Systems (CCSDS) for telemetry and telecommand.

3.3.1.9 Mass Allocations

3.3.1.9.1 Observatory Mass
The total mass of the observatory at launch including fuel shall not exceed 4627 kg. The observatory mass allocation does not include the payload adapter fitting (PAF).

3.3.1.9.2 Spacecraft Mass
The mass of the spacecraft including propellant and contingency shall not exceed 1512 kg. The spacecraft mass allocation does not include the PAF. CH-09

3.3.1.9.3 LAT Mass
The mass of the LAT including contingency shall not exceed 3000 kg.

3.3.1.9.4 GBM Mass
The mass of the GBM including contingency shall not exceed 115 kg. CH-09

3.3.1.10 Payload Power Allocations

3.3.1.10.1 LAT Power
The orbit average power for the LAT including contingency shall not exceed 650 W.

3.3.1.10.2 GBM Power
The orbit average power for the GBM including contingency shall not exceed 65 W.

3.3.1.11 Pointing Knowledge Allocations
The contributions to the radius of the pointing knowledge error circle apportioned below shall support the determination of the direction of any observed gamma-ray event, regardless of the direction of the event.

3.3.1.11.1 LAT-SC System

A pointing knowledge requirement of 10 arc seconds, 1 sigma, radial, for the LAT-SC system shall be met by the following end-to-end error budget over the life of the mission, see Figure 3-2. The end-to-end spacecraft-LAT system error considered here does not include the LAT point spread function (PSF). CH-01

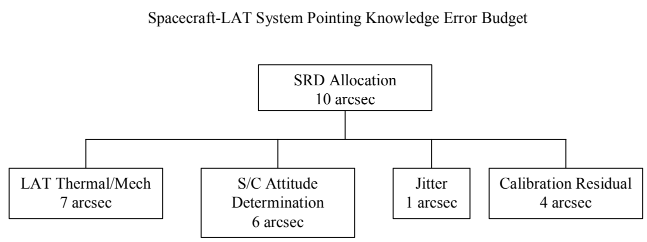


Figure 3-2 Spacecraft-LAT Pointing Knowledge Error Budget CH-01

3.3.1.11.1.1 Spacecraft Attitude Determination

Spacecraft attitude determination errors with respect to the LAT interface plane, defined in the LAT IRD, 433-IRD-0001, shall be less than 6 arc seconds, 1 σ, radial.

3.3.1.11.1.2 LAT Thermal Mechanical

Thermal-mechanical stability of the LAT relative to the LAT interface plane shall be less than 7 arc seconds, 1 σ, radial.

3.3.1.11.1.3 System Structural Dynamics

Structural dynamics errors for the LAT-spacecraft system, including jitter, shall be less than 1 arc second, 1 σ, radial, over periods less than or equal to twice the GNC sample period, between the Observatory and the LAT coordinate systems. CH-01

3.3.1.11.1.4 Calibration Residual

Residual errors in on-orbit LAT-spacecraft alignment calibration shall be less than 4 arc seconds, 1σ, radial.

3.3.1.11.2 GBM-SC System

A pointing knowledge requirement of 6 arc minutes, 1 sigma, radial, for the GBM-SC system shall be met by the following end-to-end error budget, see Figure 3-3. This budget only applies to the 12 NaI detectors. The term “GBM interface plane” is defined as the SC to GBM NaI detector mechanical interface plane for an individual NaI detector. CH-01

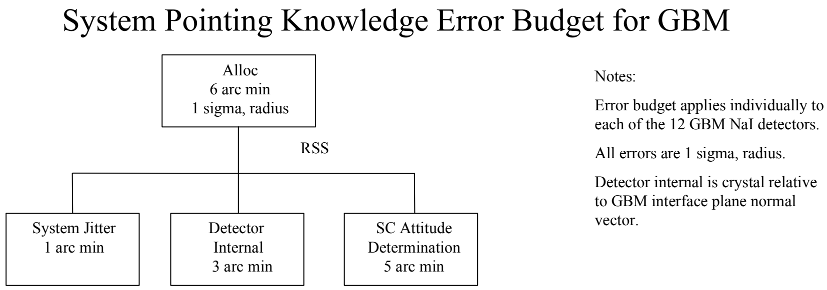


Figure 3-3 Spacecraft-GBM Pointing Knowledge Error Budget CH-01

3.3.1.11.2.1 Spacecraft Attitude Determination

Spacecraft attitude determination errors with respect to an individual GBM interface plane (each of 12) shall be less than 5 arc minutes, 1 σ, radial.

3.3.1.11.2.2 Detector Internal

Internal misalignment of an NaI detector crystal relative to its GBM interface plane normal vector shall be less than 3 arc minutes, 1 σ, radial.

3.3.1.11.2.3 System Structural Dynamics

Structural dynamics errors for the GBM-spacecraft system, including jitter, shall be less than 1 arc minute, 1 σ, radial, over periods less than or equal to twice the GNC sample period, between the Observatory coordinate system and each GBM interface plane. CH-01

3.3.1.12 Time Accuracy

The observatory time accuracy shall be maintained within 10 μsec (with a goal of within 3 μsec) relative to Universal Time Coordinated (1 sigma rms). CH-05

3.3.1.13 Absolute Pointing Accuracy

The observatory shall maintain pointing of the observatory +Z axis in the observation modes within 2 degrees, 1 sigma, radial, with a goal of 0.5 degrees, 1 sigma, radial, of its commanded direction.

3.3.1.14 Absolute Position Accuracy

The absolute accuracy for on-board, real-time determination of the observatory position in orbit in any direction (spherical error) shall be less than 3.3 km, 3 sigma, with a goal of less than 1 km.

3.3.2 Observatory Functional Requirements

3.3.2.1 General Operational Requirements

3.3.2.1.1 Ground Commanded Repointing

The observatory shall be capable of repointed observations in all modes of observation upon ground command.

3.3.2.1.2 GRB Alert Transmission

The observatory shall transmit GRB alert messages in all modes of observation.

3.3.2.1.3 Sequences of Observations

The observatory shall be capable of executing sequences of pointed and scanning observations from on-board command storage.

3.3.2.1.4 Data Acquisition

The observatory shall be designed to accommodate instrument data rates and volumes as defined in the LAT and GBM IRDs.

3.3.2.1.5 Data Storage

The observatory shall have the capability to acquire and store up to 30 hours of science and 36 hours of housekeeping data between telemetry contacts. CH-08

3.3.2.1.6 Communications

3.3.2.1.6.1 Grade of Service

The observatory shall implement CCSDS Grade of Service 2 on all GN and TDRS-SA return links as defined in CCSDS 701.0-B-3. CH-06

3.3.2.1.6.2 Ground Network

The observatory shall communicate via the ground network at the rates and frequencies given in table 1.

3.3.2.1.6.3 Space Network

The observatory shall communicate with the ground via the space network at the rates and frequencies given in table 2.

3.3.2.1.7 Pointing

The observatory shall be able to point the +Z axis of the observatory in any direction subject to operational constraints identified in the Spacecraft Performance Specification.

3.3.2.1.8 Downlink Data Volume Margin

The observatory shall be capable of supporting the number of downlinks necessary to transfer twice the observatory daily average data volume to the ground. The observatory daily average data volume is defined as the sum of the instrument data volumes specified in the SC-instrument IRDs for a 24 hour period plus the average spacecraft daily orbit data volume for a 24 hour period.

3.3.2.2 Sky Survey Mode

3.3.2.2.1 Orbit Fixed Referenced Pointing

The desired pointing direction of the +Z axis of the observatory shall be defined with respect to the orbit fixed frame. The desired rocking angle may be piecewise constant, or may vary slowly (small multiples of orbit frequency) with time. CH-06

3.3.2.2.2 Rocking

Rocking angle offsets of the observatory Z-axis shall range from –60 deg. to 60 deg.

3.3.2.2.3 Pointing Accuracy

The observatory shall maintain the +Z-axis to within 2 degrees, 1 sigma, radial, with a goal of 0.5 degrees, of its commanded direction.

3.3.2.2.4 Sky Coverage

The observatory shall be capable of scanning the LAT field of view (55 degree half-angle) over >90% of the celestial sphere repetitively on selectable timescales as short as every 2 orbits. CH-05

3.3.2.2.5 Data Acquisition

Downlink transmissions of science data shall not degrade the on-going acquisition of science data.

3.3.2.2.6 Downlink Transmission

Downlink transmissions of science data shall not be interrupted by a repointing candidate request from the science instruments.

3.3.2.2.7 Mode Transitions

Transition to and from sky survey mode shall occur upon real-time ground command or delayed-time stored command.

3.3.2.3 Pointed Observation Mode

3.3.2.3.1 Pointing Accuracy

The observatory shall maintain pointing of the observatory +Z axis to within 2 degrees, 1 sigma, radial, with a goal of 0.5 degrees, 1 sigma, radial, of its commanded pointing direction.

3.3.2.3.2 Earth Avoidance Angle

The Earth Avoidance Angle shall be a parameter that is adjustable on orbit.

3.3.2.3.3 Earth Avoidance Angle Initial Value

CH-01

The initial value of the Earth Avoidance Angle shall be 30 degrees.

3.3.2.3.4 Earth Avoidance Constraint

The observatory shall not point the +Z observatory axis to within the Earth Avoidance Angle of any portion of the Earth, except during a repointing slew or by ground command.

3.3.2.3.5 Target Within the Earth Avoidance Angle of the Earth

When the observation target is unocculted but within the Earth Avoidance Angle of the Earth, the observation target shall be maintained within the Earth Avoidance Angle of the +Z Observatory axis.

3.3.2.3.6 Pointing Adjustment

When the observation target is occulted, or unocculted but within the Earth Avoidance Angle of the Earth, the commanded pointing direction shall be adjusted by the spacecraft to accommodate the Earth avoidance constraint. CH-01

3.3.2.3.7 Secondary Target Repointing

The observatory shall have the capability to slew and point to a secondary target (if previously identified) when the primary target is occulted by the Earth.

3.3.2.3.8 Primary Target Repointing

The observatory shall return from a secondary target to its primary target when the primary target is no longer occulted by the Earth.

3.3.2.3.9 Downlink Transmissions

3.3.2.3.9.1 Priority CH-01

Downlink transmissions of science data in pointed observation mode shall take priority over on-going pointed observations.

CH-01

3.3.2.3.9.2 Interruption of Pointed Observation

An on-going pointed observation may be interrupted to meet the pointing constraints for downlink transmissions of science data.

CH-01

3.3.2.3.10 Mode Transitions

Transition to and from pointed observation mode shall occur upon real-time ground command or time-delayed stored command.

3.3.2.4 Repoint Mode

3.3.2.4.1 Autonomous Repointing

The observatory shall be capable of repointing autonomously from either sky survey mode or pointed observation mode in response to GRBs detected on board.

3.3.2.4.1.1 Go/No-Go Decision Making

The observatory shall be capable of go/no-go decision making in response to on-board repointing commands.

3.3.2.4.1.2 Automatic Resume

Upon completion of a repointed observation that is performed autonomously, the observatory shall automatically resume the previously interrupted observation (sky survey or pointed observations).

3.3.2.4.2 Targets of Opportunity

The observatory shall accept repointing commands from the ground to acquire Targets of Opportunity.

3.3.2.5 Delta-V Mode

The observatory shall have a Delta-V mode to support controlled de-orbit functions.

3.3.2.6 Data Handling

3.3.2.6.1 Virtual Recorders

The observatory shall organize its data for storage and transmission using different virtual recorders for LAT, GBM, and spacecraft data.

3.3.3 Maintainability Requirements

3.3.3.1 Normal Maintenance Information

The observatory shall normally report telemetry relevant to its health.

3.3.3.2 Information for Diagnostics and Anomalous Conditions

The observatory shall have the capability to increase the rate and amount of any or all engineering telemetry to the degree necessary to support observatory diagnostics and to troubleshoot anomalies or failures.

3.3.3.3 Reconfiguration for Trouble Shooting

To assist in troubleshooting anomalies or failures, the observatory shall have the capability to safely reconfigure its state by command. (Such state changes may include but are not limited to the attitude of the observatory, the position of movable hardware, battery charge rates, power to heaters, power to various equipment and so forth.)

3.3.3.4 Impact on Science

3.3.3.4.1 Diagnostics and Troubleshooting CH-05

The observatory shall include functionalities to enable mission operations personnel to conduct diagnostics and troubleshooting procedures. CH-05

3.3.3.5 Software Uploads

The observatory shall accommodate software uploads for the instruments and the spacecraft.

3.3.3.6 Real Time Communications

The observatory shall support full-orbit coverage via TDRSS for real-time telemetry and command.

3.3.4 Observatory Safety Requirements

3.3.4.1 Autonomous Fault Protection System

The observatory shall perform autonomous on-board fault detection, isolation, and correction for mission-critical functions where faults could cause damage, loss of control, or loss of science if not corrected immediately.

3.3.4.1.1 Fault Detection

The observatory shall continually monitor its mission-critical functions during on-orbit operation for faults.

3.3.4.1.2 Fault Isolation

The observatory shall be designed to isolate faults to prevent propagation and to take corrective actions in case of mission-critical faults.

3.3.4.1.3 Fault Correction

The observatory shall implement a hierarchical fault correction system to continue safe operation if possible, or to command safe mode entry if necessary.

3.3.4.1.4 Fault Notification

The observatory shall provide notification of all faults detected, isolated, or corrected in telemetry, and shall capture all relevant data necessary for anomaly analysis.

3.3.4.2 Safe Mode Environment

The observatory shall provide a safe mode environment that is thermal and power safe indefinitely.

3.3.4.3 Safe Mode Alert

The observatory shall transmit a safe mode alert message upon entering safe mode.

3.3.5 Observatory System Interfaces

3.3.5.1 Space Environment Performance Requirements

3.3.5.1.1 Orbit Environment

3.3.5.1.1.1 Exposure

The observatory shall be designed to meet all of its requirements over its required operational lifetime during and after exposure to both natural and induced environments throughout operation in orbit.

3.3.5.1.1.2 Environments

The environments considered in the observatory design shall include, but not be limited to, radiation, charged particles, atomic oxygen, micrometeoroids, and debris.

3.3.5.1.2 SAA Safeguard

The observatory shall provide a safe configuration to protect itself from charged particle radiation within the boundaries of the SAA.

3.3.5.1.3 Micrometeoroid Environment

The observatory shall operate in the micrometeoroid environment, given in section 3.3.6, for the mission orbit and operational lifetime while meeting its reliability requirement.

3.3.5.1.4 Debris Environment

The observatory shall operate in the debris environment, given in section 3.3.6, for the mission orbit and operational lifetime while meeting its reliability requirement.

3.3.5.1.5 Radiation Environment

The observatory shall be designed to meet its performance requirements in the radiation environment given in Section 3.3.6. These environments are valid for launch dates between March 2006 and March 2007.

3.3.5.2 Launch Environment

The observatory shall survive the launch environment (vibration, pressure differentials, and temperature), as characterized in the Payload Planners Guide for the baseline launch vehicle, with no degradation to its operational capability or performance. The observatory shall survive the acoustics environment specified in section 3.2.5.2 of the Spacecraft Performance Specification, 433-SPEC-0003.

3.3.5.3 Launch Vehicle Constraints

The observatory shall meet the constraints of the launch vehicle (mass, envelope, and location of center of gravity) as defined in the Payload Planners Guide for the baseline launch vehicle.

3.3.5.4 TDRSS Constraint

The observatory shall be compatible with the existing space network (TDRSS).

3.3.5.5 Ground Station Constraint

The observatory shall interface with existing ground stations for direct to ground telemetry of observatory data.

3.3.5.6 GPS Constraint

The observatory shall be compatible with the existing GPS Constellation.

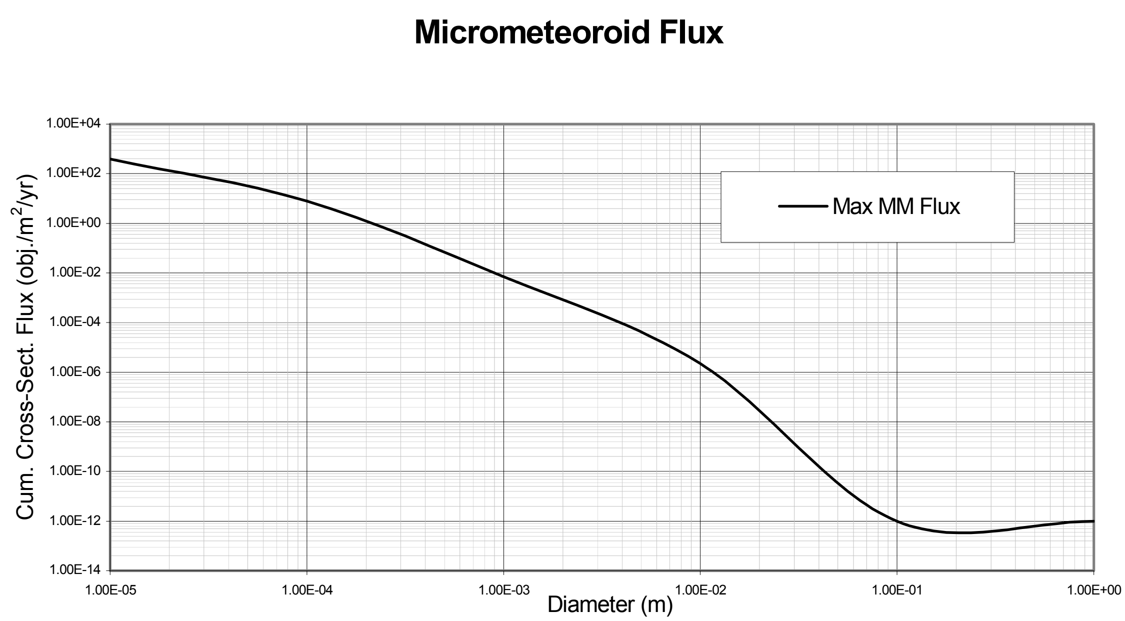
3.3.6 Space Environments

3.3.6.1 Micrometeoroid and Debris Flux

3.3.6.1.1 Micrometeoroid Flux

The micrometeoroid environment for the observatory is specified below in Figure 3-4 and Table 3. Micrometeoroid impacts are assumed to come from any random direction. A worst case orbital altitude of 575 km was used to generate this environment. CH-03

The micrometeoroid environment encompasses only particles of natural origin. The mass density for micrometeoroids varies according to the size of the micrometeoroid. The micrometeoroid flux was computed using the Debris Assessment Software (DAS) available from ftp://jsc-sn-io.jsc.nasa.gov/Anonymous/SpaceScience/DocRepo/Download/DAS153. CH-03
The micrometeoroid environment within DAS is taken from the Space Station Program Natural and Induced Environment Definition for Design, SSP 30425 Revision B, Feb 8, 1994.



CH-03

Figure 3-4 Micrometeoroid Flux

Object size (m)	Max MM Flux (hits/m^2/yr)
1.00E-05	3.88E+02
1.00E-04	7.78E+00
1.00E-03	7.09E-03
1.00E-02	2.21E-06
1.00E-01	1.00E-12
1.00E+00	1.00E-12

CH-03

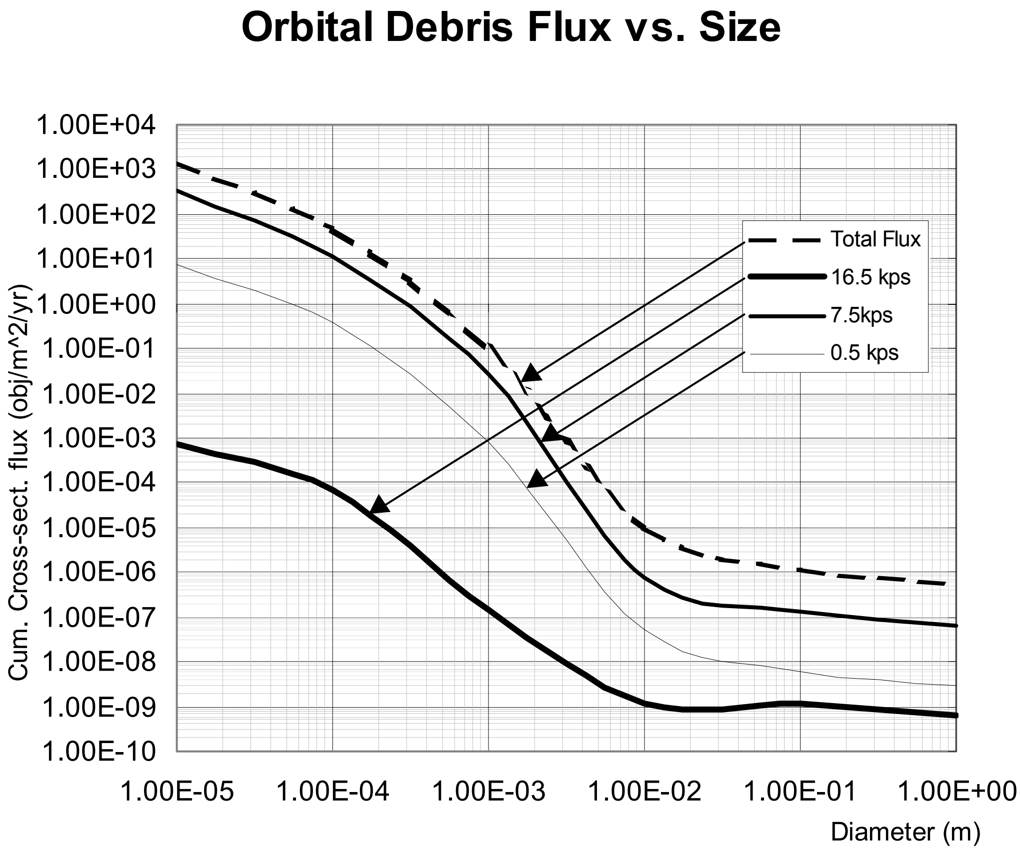
CH-09

Table 3. Debris Assessment Software Results

3.3.6.1.2 Debris Flux

The debris environment for the observatory is specified below in Figure 3-5 and Table 4. The output gives the flux for the velocity distribution without regard to direction. Theoretically, the summation of fluxes for all velocities will equal the total flux curve. In addition to the total flux, three cases are plotted in Figure 3-5 – a minimum velocity, a maximum velocity, and a nominal expected velocity. CH-03

The orbital debris environment is composed of residue from man-made satellites and launch vehicles. The debris flux was computed using Orbital Debris Model, ORDEM2000, available from the following site: CH-03
ftp://jsc-sn-io.jsc.nasa.gov/Anonymous/SpaceScience/DocRepo/Download/ORDEM2000. CH-03



CH-03

Figure 3-5 Man-made Debris Flux

Particle Velocity [km/sec]: Object size [m]	0.5 kps [obj/m^2/yr]	7.5kps [obj/m^2/yr]	16.5 kps [obj/m^2/yr]	Total Flux [obj/m^2/yr]
1.00E-05	7.72E+00	3.27E+02	7.06E-04	1.40E+03
1.00E-04	3.69E-01	1.20E+01	7.01E-05	4.94E+01
1.00E-03	8.53E-04	2.66E-02	1.43E-07	1.06E-01
1.00E-02	5.34E-08	7.58E-07	1.17E-09	9.72E-06
1.00E-01	6.10E-09	1.29E-07	1.17E-09	1.17E-06
1.00E+00	3.03E-09	6.49E-08	6.59E-10	5.33E-07

Table 4. Output Results from ORDEM2000 Display Average Flux vs. Size. Butterfly Module Used for Velocities

3.3.6.2 Radiation Environment

3.3.6.2.1 Total Ionizing Dose

3.3.6.2.1.1 Component TID Specification

Note: In the context of radiation environment requirements, the word “component” shall be defined to mean an active part, such as a microcircuit, electro-optical device, diode, etc., excluding solar cells. Radiation effects for solar cells shall be considered separately.

Electronic components shall be allowed for consideration for use on the mission if one of the following holds:

(1) The component has been successfully used on a previous mission with a TID environment at least as severe as the planned mission and meets the following requirements: same lot date code (LDC), same application, and same shielding. If components from the same LDC are not available but the manufacturer's technology and processing can be verified to be unchanged, usage shall still be considered acceptable if the application and shielding requirements are met.

(2) Test data for the component exists which shows the component operates within its specifications after it is exposed to twice the top level mission dose requirement under worst-case bias and dose rate conditions. This top level dose requirement, including a standard factor of 2 safety margin used at NASA, is 4.5 krad(Si) for the 5 year GLAST mission. See Figure 3-6. CH-03

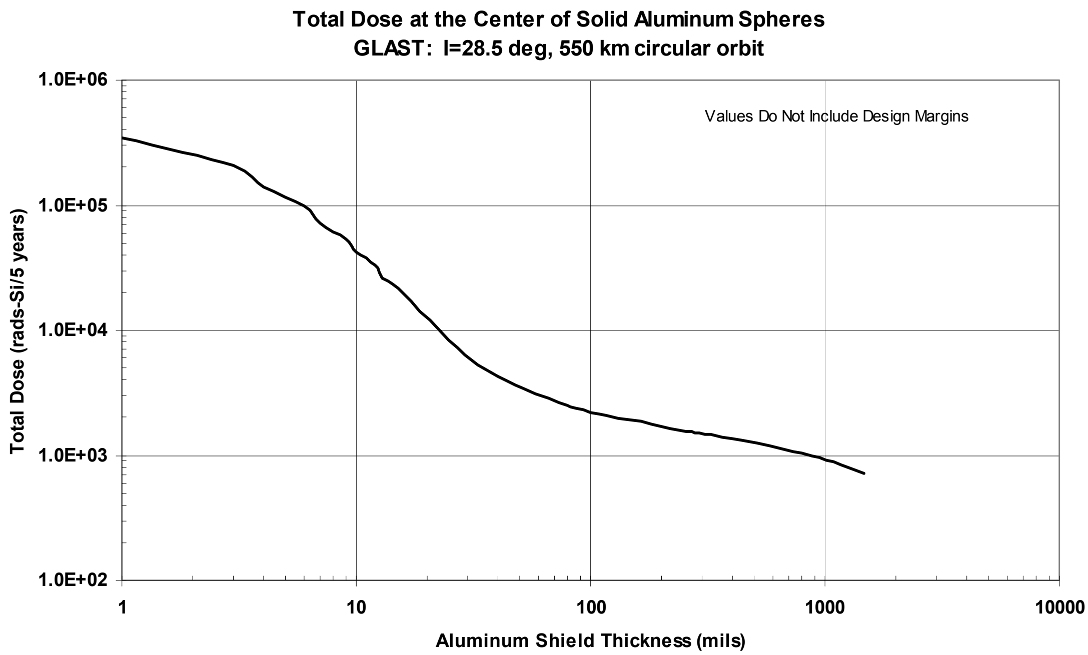


Figure 3-6 Total Dose-Depth Curve CH-03

3.3.6.2.1.2 TID Guidelines

3.3.6.2.1.2.1 Calculation of Top Level Requirement

The top level TID requirement shall be calculated assuming 100 mils of aluminum shielding in a spherical geometry.

3.3.6.2.1.2.2 Detailed Analysis

If components do not pass the top level requirement, the spacecraft vendor may request approval from the GLAST Project Office to perform a more detailed shielding analysis that may reduce the TID requirement at the location of the component in question. This more detailed analysis may include consideration of the spacecraft structure, boxes, instruments, etc.

3.3.6.2.1.2.3 Ground Testing

If test data do not exist, ground testing shall be required. For commercial components, testing shall be performed on every flight procurement lot.

3.3.6.2.2 Single Event Effects

3.3.6.2.2.1 Circuit SEE Specification

3.3.6.2.2.1.1 SEE Damage

No SEE shall cause permanent damage to a system or subsystem.

3.3.6.2.2.1.2 Immunity to SEE Induced Anomalies or Outages

Electronic circuits shall be designed to be immune to SEE induced performance anomalies, or outages which require ground intervention to correct. Electronic component reliability shall be met in the SEU environment.

3.3.6.2.2.2 Component SEE Specification

3.3.6.2.2.2.1 SEE Rate and Effects Analysis

Analysis for SEE rates and effects shall take place based on Threshold LET (LETth) of all candidate devices as follows:

Device Threshold:	Environment to be Assessed:
LETth < 15 MeV*cm2/mg	Cosmic Ray, Trapped Protons, Solar Heavy Ion and Proton
LETth = 15-37 MeV*cm2/mg	Cosmic Ray, Solar Heavy Ion
LETth > 37 MeV*cm2/mg	No analysis required

SEE immune is defined as a device having an LETth > 37 MeV*cm2/mg.

The environments used for these analyses are listed in Section 3.3.6.2.2.2.1.

3.3.6.2.2.2.1.1 Galactic Cosmic Ray Linear Energy Transfer (LET) Spectrum

The galactic cosmic ray LET spectrum which shall be used for analysis is given in Figure 3-7. CH-03

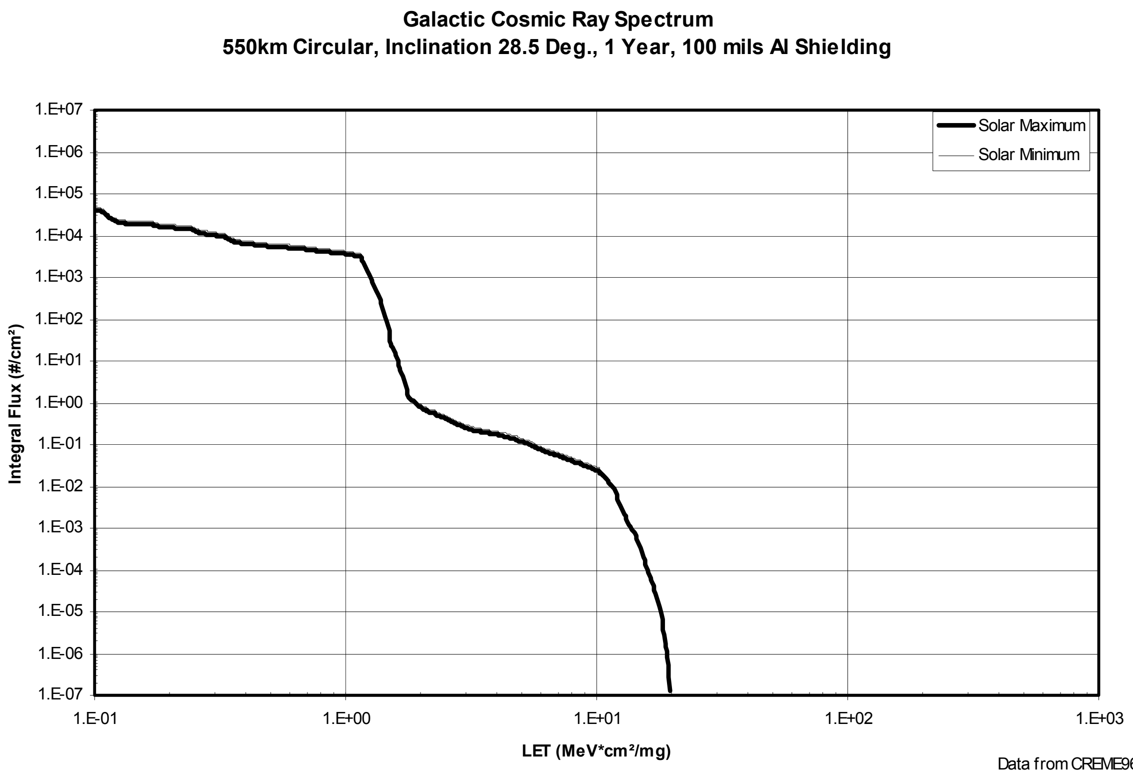
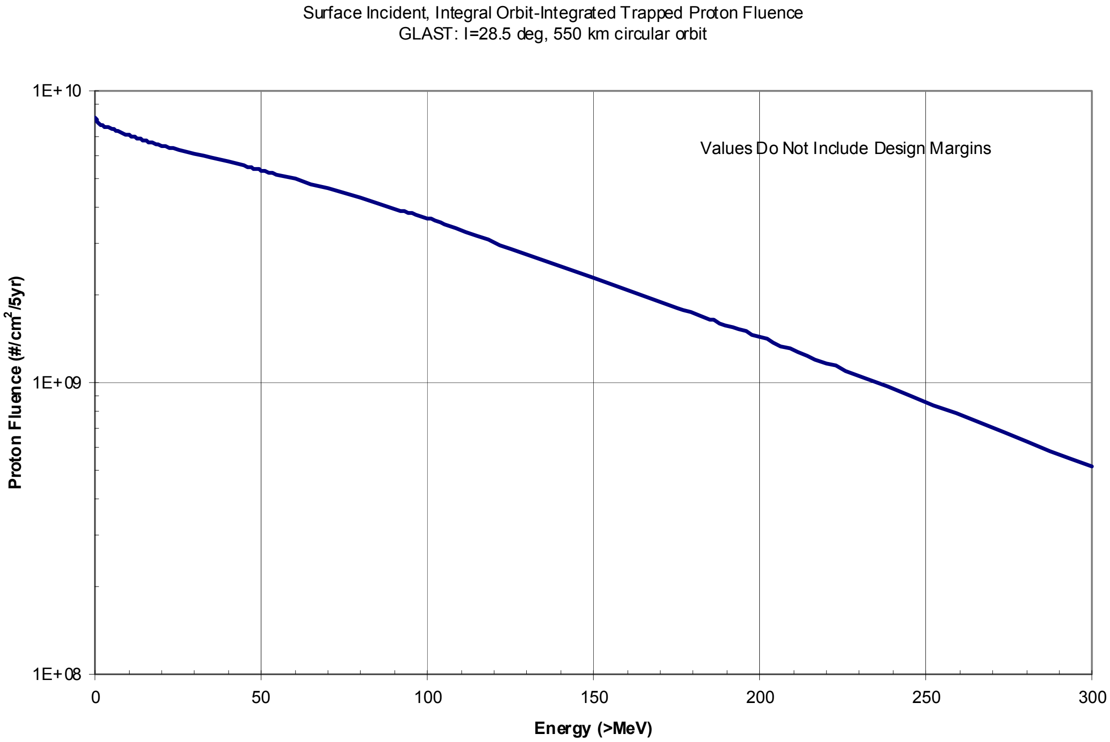


Figure 3-7 Galactic Cosmic Ray Spectrum CH-01 CH-03

3.3.6.2.2.2.1.2 Trapped Proton Environment

The trapped proton environment, which shall be used for analysis is given in Figure 3-8. Both nominal and peak particle flux rates shall be analyzed. CH-03



CH-03
CH-04a

Figure 3-8 Trapped Proton Environment

3.3.6.2.2.2.1.3 Worst Case Solar Particle Environment

The worst case solar particle environment which shall be used for analysis is given in Figure 3-9. CH-03

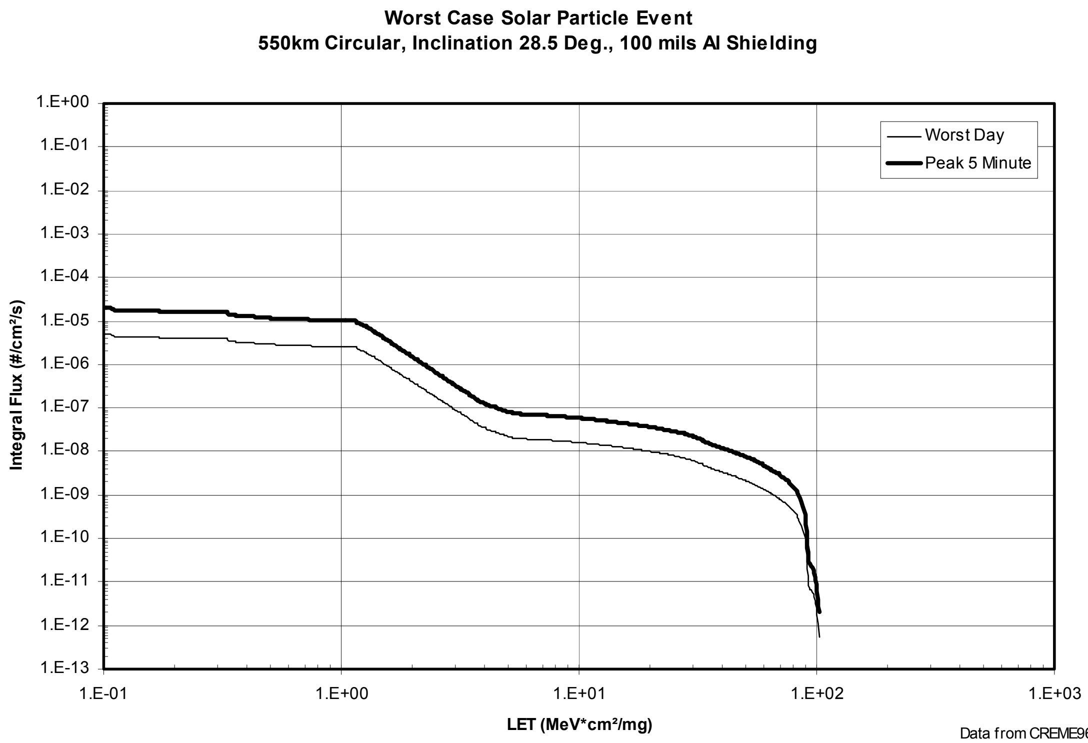


Figure 3-9 Worst Case Solar Particle Environment

CH-01

CH-03

3.3.6.2.2.2.2 Destructive SEE

Based on the SEE Rate and Effects Analysis described in Section 3.3.6.2.2.2.1, any device used that is not immune to SEL or other potentially destructive conditions, protective circuitry shall be added to eliminate the possibility of damage and verified by analysis or test.

3.3.6.2.2.2.3 Non-Destructive SEE

Based on the SEE Rate and Effects Analysis described in Section 3.3.6.2.2.2.1, any device used that is not immune to SEU, shall be shown to not degrade mission performance.

3.3.6.2.2.3 SEE Guidelines

Wherever practical, SEE immune devices shall be procured. If device test data does not exist, ground testing shall be required. For commercial components, testing shall be performed on every flight procurement lot.

3.3.6.3 Atomic Oxygen

The observatory atomic oxygen environment is calculated assuming a February 2007 launch date to 565 km altitude with +2 sigma high solar cycle applied to both the orbit decay and atomic oxygen fluence calculations. The accumulated exposure is calculated over the required five year minimum mission life. CH-03 CH-10

3.3.6.3.1 Environment for Exposed Surfaces Except the Solar Arrays CH-03

The atomic oxygen environment, which shall be used for analysis of all components except the solar arrays, is 1.03 e^{+21} atoms/cm^2. This environment incorporates the assumption that no surface will experience more than 50% of mission life in the ram direction. CH-10

3.3.6.3.2 Environment for Solar Arrays CH-10

The atomic oxygen environment, which shall be used for analysis of the solar arrays, 6.59 e^{+20} atoms/cm^2. This environment incorporates the assumption that total exposure of the solar array cell surface to the ram direction is assumed to be $1/\pi$.

3.4 Space-Ground Systems

3.4.1 General Requirements

3.4.1.1 Launch Readiness Date

The space-ground link shall support a launch readiness date as specified on the master schedule for the project.

3.4.1.2 In-Orbit Checkout

The space-ground link shall support an in-orbit checkout period of up to 60 days.

3.4.1.3 Operational Period

The space-ground systems shall support the GLAST operational lifetime of a minimum of 5 years, with a goal of 10 years, following an initial period of in–orbit checkout.

3.4.1.4 Orbit

3.4.1.4.1 Altitude

The initial orbit altitude shall be 565 km. CH-06

3.4.1.4.2 Inclination

Orbit inclination shall be equal to or less than 28.5 degrees.

3.4.1.4.3 Eccentricity
Initial orbit eccentricity shall be less than 0.01, as provided by the launch vehicle.

3.4.1.4.4 Altitude Range
The space-ground system shall meet all requirements at any orbit altitude between 575km and 450km.

3.4.1.5 Data Standards
GLAST will employ the recommendations of the Consultative Committee on Space Data Systems (CCSDS) for the transport of its data through the space-ground links.

3.4.1.6 Grade of Service

3.4.1.6.1 Space-Ground Links
The space-ground links shall provide CCSDS Grade of Service 2 on all GN and TDRS-SA return links as defined in CCSDS 701.0-B-3. CH-06

3.4.1.6.2 Ground Links
The GLAST end-to-end system shall use land line communication links that provide error-free data transmission and delivery. "Error-free" performance may be achieved through a combination of error detection and correction methods and re-transmit capability.

CH-03

3.4.2 Space Network (SN)

3.4.2.1 Extended Coverage Capability

3.4.2.1.1 In-Orbit Checkout
For the launch and early orbit checkout period, the MOC shall schedule full orbit coverage for S-band communications with the space network to support expected operations.

3.4.2.1.2 Contingencies
In case a spacecraft emergency is declared, the MOC shall schedule full orbit coverage for S-band communications with the space network to support operations.

3.4.2.2 Unscheduled Communications

3.4.2.2.1 Alert Transmission
The space network shall provide transmissions of alerts (celestial events and safe mode) from the GLAST observatory to the ground at any time during normal operations.

3.4.2.3 Communications Services

The space network shall provide the communications services at the rates and frequencies given in table 2.

3.4.3 Ground Network (GN)

3.4.3.1 Availability

3.4.3.1.1 Backup Response

At least one backup GN station shall be available within 6 to 12 hours of a problem with the primary station.

3.4.3.1.2 Extended Coverage Capability

3.4.3.1.2.1 In-Orbit Checkout

For the launch and early in-orbit checkout period, the MOC shall schedule coverage from the GN stations to support expected operations.

3.4.3.1.2.2 Contingencies

In case a spacecraft emergency is declared and coverage through the SN is not deemed adequate, the MOC shall schedule additional GN contacts.

3.4.3.2 Automation

Each GLAST GN station shall be capable of operating with an unattended MOC.

3.4.3.3 Link Communications

3.4.3.3.1 Deleted

CH-06

3.4.3.3.2 Services

Each GN station shall communicate with the observatory at the data rates and frequencies given in Table 1.

3.4.3.3.3 Deleted

CH-06

3.4.3.3.4 Deleted

3.4.3.3.5 Data Transmission Latency

Each GN station shall be capable of acquiring downlink science data and transmitting it to the MOC within 12 hours.

3.4.3.3.6 Data Buffering

The ground station shall buffer the most recent data for up to 7 days.

3.4.3.3.7 Data Retransmission on Ground

Upon request the ground station shall retransmit data within 7 days to the MOC.

3.5 Ground System Requirements

This section contains requirements that are common to the operating centers that comprise the ground system.

3.5.1 General Requirements

3.5.1.1 Ground System Architecture

The ground system consists of several interconnected operating centers, a Mission Operations Center (MOC), Instrument Operations Centers (IOC) for the LAT and for the GBM, and a Science Support Center (SSC). It is expected that the MOC will be a multi-mission operations center, while the other centers will be mission unique.

3.5.1.2 Security

The operations centers shall be interconnected by an intranet of wide area networks that is closed to, or protected from, public users of the external internet.

3.5.1.3 Autonomy

The ground system shall automatically transfer incoming downlink data, up to and including level zero data, between system elements.

3.5.1.4 Software Environment

The ground system shall support a single higher-level analysis software environment for use by the community and by the instrument teams. CH-10

3.5.1.5 Software Standards

The analysis environment shall **respect standards** that ensure software portability, independence of vendor, and compatibility with existing multi-mission high-energy astrophysics tools.

3.5.1.6 Launch Readiness Date

The ground system shall support a launch readiness date as specified on the master schedule for the project.

3.5.1.7 In-Orbit Checkout Period

The ground system shall support an in-orbit checkout period of up to 60 days.

3.5.1.8 Operational Period

The ground system shall support an operational lifetime of a minimum of 5 years, with a goal of 10 years, following an initial period of in–orbit checkout.

3.5.1.9 Orbit

3.5.1.9.1 Altitude

The initial orbit altitude shall be 565 km. CH-06

3.5.1.9.2 Inclination

Orbit inclination shall be equal to or less than 28.5 degrees.

3.5.1.9.3 Eccentricity

Initial orbit eccentricity shall be less than 0.01, as provided by the launch vehicle.

3.5.1.9.4 Altitude Range

The ground system shall meet all requirements with the observatory at any orbit altitude between 575km and 450km.

3.5.1.10 Coordinate Systems

3.5.1.10.1 Inertial The ground system shall use the J2000 inertial coordinate system.

3.5.1.10.2 Right Ascension and Declination
RA and DEC shall be used as a standard means of receiving and communicating pointing directions.

3.5.1.11 Data Communications
The GLAST ground system shall use land line communication links that provide error-free data transmission and delivery. "Error-free" performance may be achieved through a combination of error detection and correction methods and re-transmit capability.

3.5.1.12 Units of Measurement
The ground system shall observe the current NASA policy directive, NPD 8010.2C, Use of the Metric System of Measurement in NASA programs.

The ground system shall use metric units with the following exceptions: Angular measure may be expressed in degrees, minutes, and seconds; Photon and particle energy may be expressed in eV; and English units may be used for mechanical fabrication.

3.5.2 Ground System Functional Requirements

3.5.2.1 Observatory Operation

3.5.2.1.1 Reorientation for Downlink
The ground system shall reorient the observatory as needed to within the pointing envelope of the sky survey mode for downlink transmissions of science data.

3.5.2.1.2 Calibration Observations
The ground system shall use the observatory in pointed observation mode to acquire observation data on known celestial sources.

3.5.2.2 Observatory Maintenance
The ground system shall maintain the observatory during its operational life.

3.5.2.2.1 Ground-Based Troubleshooting
The ground system shall be capable of resolving flight hardware and software faults and anomalies from the ground.

3.5.2.2.2 Software Loads
The ground system shall perform uploads of flight software for the instruments and spacecraft.

3.5.2.2.3 SAA Boundaries
The ground system shall maintain SAA boundary definitions relative to the spacecraft during the course of the mission as a function of time.

3.5.2.3 Observing Plans

The ground system shall carry out the observing plans of GLAST investigators.

3.5.2.4 Data Handling

3.5.2.4.1 VCDU Service

The ground system shall accommodate the multiplexed virtual channel data unit (VCDU) service of the CCSDS.

3.5.2.4.2 Telemetry Data

The ground system shall be capable of downlinking up to 36 hours of recorded science and housekeeping telemetry data. For the purposes of this requirement the data is assumed to be continuously collected at orbit averaged rates.

3.5.2.4.3 Packets

3.5.2.4.3.1 Packetized Data

The ground system shall accommodate instrument data that is compliant with CCSDS Packet Telemetry Recommendations as defined in Series 100 Blue Books.

3.5.2.4.3.2 Ancillary Data

The ground system shall accommodate source data packets for science data that contain the ancillary data from the spacecraft that is necessary for stand-alone processing.

3.5.2.4.4 Data Loss

The total data loss in the data delivery part of the GLAST system, excluding Spacecraft Data Loss, shall be less than 1.9% with a goal of less than 0.9%. CH-03

3.5.2.5 Data Processing

The LAT and GBM IOCs shall have the capability to generate instrument data products at a rate that is greater than twice the orbit average rate at which it is acquired by the observatory.

3.5.2.6 Data Products

The ground system shall generate high-level data products (sky maps, source catalogs).

3.5.2.7 Targets of Opportunity

3.5.2.7.1 Ground System Coordination

The ground system shall coordinate with other observatories for selected observations of targets such as AGN flares.

3.5.2.7.2 Time to Respond to TOO's on Ground

The SSC and MOC shall plan and send a spacecraft repointing command in less than 6 hours (goal is less than 4 hours) after the decision is made to respond to a Target of Opportunity. CH-05

3.5.2.8 Alerts

The ground system shall send alerts of gamma-ray bursts and other transients to other observatories.

3.5.2.9 Repointing Capability

The ground system shall be capable of ground-based repointing for gamma-ray bursts and other transients that are detected on board the observatory.

3.5.2.10 Archival Research

The ground system, in conjunction with the HEASARC, shall support archival research and multi-wavelength studies during, as well as after, the operation period of the mission.

3.5.2.11 Data Archives

The ground system shall permanently archive all mission data during and after the operational period of the mission.

3.5.3 External Interfaces

3.5.3.1 Space-Ground Link

3.5.3.1.1 MOC Interface

The MOC shall be the sole interface for commands between the elements of the ground system and the space-ground communications links.

3.5.3.1.2 Communications

The ground system shall communicate with the observatory via the space-ground link using the communication modes and data rates given in tables 1 and 2.

3.5.3.2 GPS

The ground system shall be capable of determining observatory orbit independently from GPS data in observatory telemetry data.

3.5.3.3 GCN

The ground system shall interface with the Gamma-ray burst Coordinates Network for communications of alerts of celestial events with other observatories.

3.5.3.4 HEASARC

The ground system shall interface with the High Energy Astrophysics Science Archive Research Center (HEASARC) in support of multi-wavelength studies.

3.5.3.5 External Users

The ground system shall interface with GLAST investigators via the commercial internet. The ground system shall provide access to GLAST data that is made public via the commercial internet.